Evaluating the Adsorptive Capacities of Chemsorb 1000 and Chemsorb 1425

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Chemsorb 1000

Chemsorb 1425

The Air Revitalization Lab at KSC tested Chemsorb 1000 and 1425, two candidate sorbents for use in future air revitalization technologies being evaluated by the ARREM project. Chemsorb 1000 and 1425 are granular coconut-shell activated carbon sorbents produced by Molecular Products, Inc. that may be used in the TCCS. Chemsorb 1000 is a high grade activated carbon for organic vapor adsorption. In contrast, Chemsorb 1425 is a high-grade impregnated activated carbon for adsorption of airborne ammonia and amines. Chemsorb 1000 was challenged with simulated spacecraft gas streams in order to determine its adsorptive capacities for mixtures of volatile organics compounds. Chemsorb 1425 was challenged with various NH_3 concentrations to determine its adsorptive capacity.

Nomenclature

AES	=	Advanced Exploration Systems
ARREM	=	Atmosphere Resource Recovery and Environmental Monitoring

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B-S	=	Barnebey Sutcliffe
FTIR	=	fourier transform infrared spectroscopy
KSC	=	Kennedy Space Center
LEO	=	Lower Earth Orbit
RVCS	=	Regenerable VOC Control System
VOC	=	volatile organic compound
SLPM	=	standard liters per minute
SOA	=	state-of-art
TCCS	=	Trace Contaminant Control Subassembly

I. Introduction

THe removal of trace contaminants from spacecraft cabin air is necessary for crew health and comfort during long duration space exploration missions. The air revitalization technologies used in these future exploration missions will evolve from current ISS State-of-Art (SOA) and is being designed and tested by the Advanced Exploration Systems (AES) Program's Atmosphere Resource Recovery and Environmental Monitoring (ARREM) project[1]. The ARREM project is working to mature optimum atmosphere revitalization and environmental monitoring system architectures to enable exploration beyond Lower Earth Orbit (LEO). The Air Revitalization Lab at the Kennedy Space Center (KSC) is one of six NASA field centers participating in the ARREM project. The lab specializes in adsorbent and catalyst characterization with simulated spacecraft gas streams using combinations of pressure, O_2 partial pressure, CO_2 partial pressure, and humidity that are representative of a range of anticipated cabin atmospheric conditions and loads.

On board ISS, the Trace Contaminant Control Subassembly (TCCS) provides active control of trace contaminants from the cabin atmosphere utilizing physical adsorption, thermal catalytic oxidation, and chemical adsorption processes.[2] High molecular weight contaminants and ammonia (NH_3) are removed by a granular activated carbon treated with ~ 10% by weight phosphoric acid (H_3PO_4) (B-S Type 3032 4×6 mesh), which is expendable and is periodically refurbished[3]. The Type 3032 granular activated carbon bed is no longer commercially available and therefore it is important to characterize the efficiency and capacity of commercially available NH_3 sorbents.

This paper describes the characterization of two Molecular Products LTD activated carbons: Chemsorb 1000 and Chemsorb 1425. Untreated activated carbons (e.g. Chemsorb 1000) remove contaminants by physisorption, which concentrates the contaminant within the pores of the carbon while letting air to pass through the sorbent[4]. Low molecular weight or polar gases (e.g. HCl, SO_2, formaldehyde, and NH_3) are not removed by physisorption and typically require chemisorption for removal. Treated activated carbons (e.g. Chemsorb 1425) are impregnated with a a chemical agent (e.g. phosphoric acid) that reacts with NH_3, converting it to a salt within the carbon and removes it from the air stream. This process occurs via neutralization or catalysis reactions and adsorption capacity is exhausted when the available impregnated chemicals are consumed. Moisture affects removal performance since adsorption sites within the pores are filled with water. The performance of impregnated carbons may be enhanced by moisture content because the mechanisms of contaminant removal are chemical reactions that occur in reagents contained within the pores. The adsorptive capacity data (mmol/kg) of Chemsorb 1000 and 1425 for gas mixtures (ethanol, acetone, toluene, acetaldehyde, dichloromethane, and xylene) was measured with 40% relative humidity at 23 ^{0}C air temperature. The adsorptive capacity data (mol/kg) of Chemsorb 1425 was measured using NH_3 gas streams.

II. Experimental Methods

Simulated cabin air gas streams (humidified gas mixtures) were supplied at 1-2 SLPM to 3-5 g of Chemsorb 1000 (4x8 US mesh size) or Chemsorb 1425 (12x20 US mesh size) in the ½ inch-diameter x 2 inch long sorbent bed of the Regenerable VOC Control System (RVCS) testbed[5].

- Gas mixture analysis was conducted using an FTIR spectrometer (Model DX-4030, Gasmet Technologies, Finland). The FTIR was zeroed with dry N_2 prior to use.
- The gastream VOC mixture was supplied using a Kintek gas generator.
- The tests were run for 10-16 hr to ensure maximum adsorption was reached.

III. Results

A. Adsorptive Capacity

A rapid screening methodology was developed to compare the adsorptive capacities of Chemsorb 1000 and 1425.The adsorptive capacity here is defined as the cumulative amount of 5 ppm of VOC removed during the period of 1 hour. The reason for this definition is that measurement of the total adsorptive capacity for a given VOC may not be possible in a reasonable amount of time. For example, moist Chemsorb 1000 adsorbs the toluene supplied to the bed for up to 19 hours, however, ethanol reaches its maximum capacity in that same amount of time (Fig 1). Reporting the 1-h adsorptive capacity is useful for comparing among sorbents, and for estimating bed sizes of air revitalization systems. A better procedure based on adsorption in a closed loop is being developed for determining adsorptive capacity.

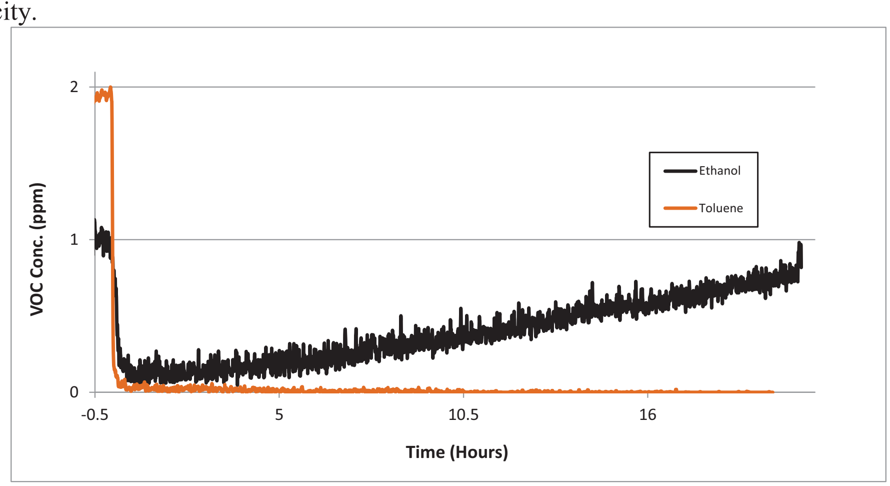

Figure 1. *Breakthrough curves for the adsorption of ethanol and toluene by Chemsorb 1000. Ethanol breakthrough occurs after 3 hrs. The breakthrough time denotes the point at which the mass transfer zone reaches the end of the bed and contaminant is detected in the effluent gas stream.*

B. Chemsorb 1000

Chemsorb 1000 is a high grade activated carbon for organic vapor adsorption. Its adsorptive capacity for water is 0.27 mol/kg, and it is 0.0156 mol/kg for CO_2 when dry or wet. The 1-h adsorptive capacities for volatile organic compounds (VOCs) were determined by exposing Chemsorb 1000 to dry (0% RH) and wet (40-50% RH) gas mixtures (Fig 2).

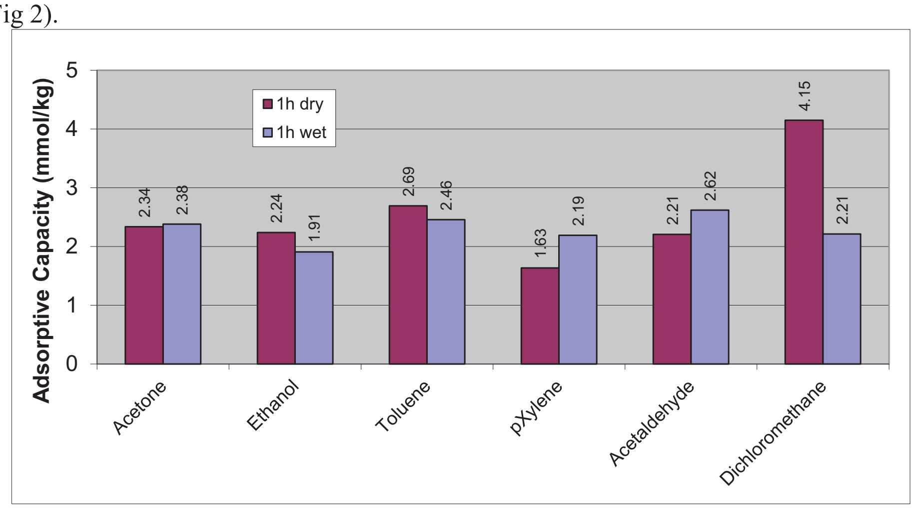

Figure 2. *1-h Adsorptive capacities of Chemsorb 1000 for several VOCs under dry and wet (40-50% RH) gas streams.*

C. Chemsorb 1000 and Barnebey Sutcliffe Type 3032

The adsorptive capacity of Barnebey Sutcliffe Type 3032 activated carbon was determined in the RVCS using similar conditions used with Chemsorb 1000. Fig 3 shows that the 1-h adsorptive capacities for acetone, ethanol, and toluene at 40-50% RH of B-S Type 3032 are 65-80% higher for than for Chemsorb 1000.

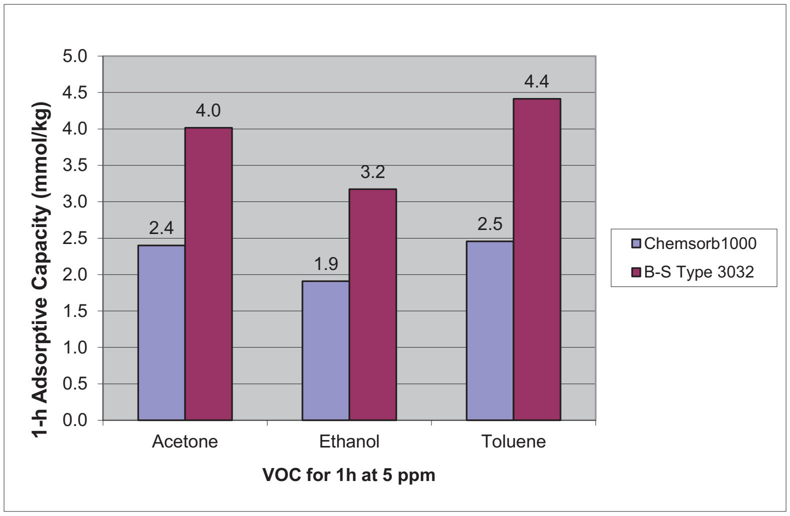

Figure 3. *Comparison of 1-h Adsorptive capacities of moist Chemsorb 1000 vs B-S Type 3032 for acetone, ethanol, and toluene. The B-S Type 3032 had significantly higher 1-h capacities than Chemsorb 1000.*

D. Chemsorb 1000 and Chemsorb 1425

Chemsorb 1425 is a high-grade impregnated activated carbon adsorption of airborne ammonia and amines. The 1-h adsorptive capacities for volatile organic compounds (VOCs) were determined by exposing Chemsorb 1425 to wet (40-50% RH) gas mixtures. The adsorptive capacities of moist Chemsorb 1425 and Chemsorb 1000 are compared in Fig 4. Generally, Chemsorb 1000 adsorbs more toluene, dichloromethane (DCM), xylene, and acetaldehyde than Chemsorb 1425. These differences in adsorption may be influenced by the different particle sizes between the two sorbents, as no attempt was made to compare equal mesh sizes in this study.

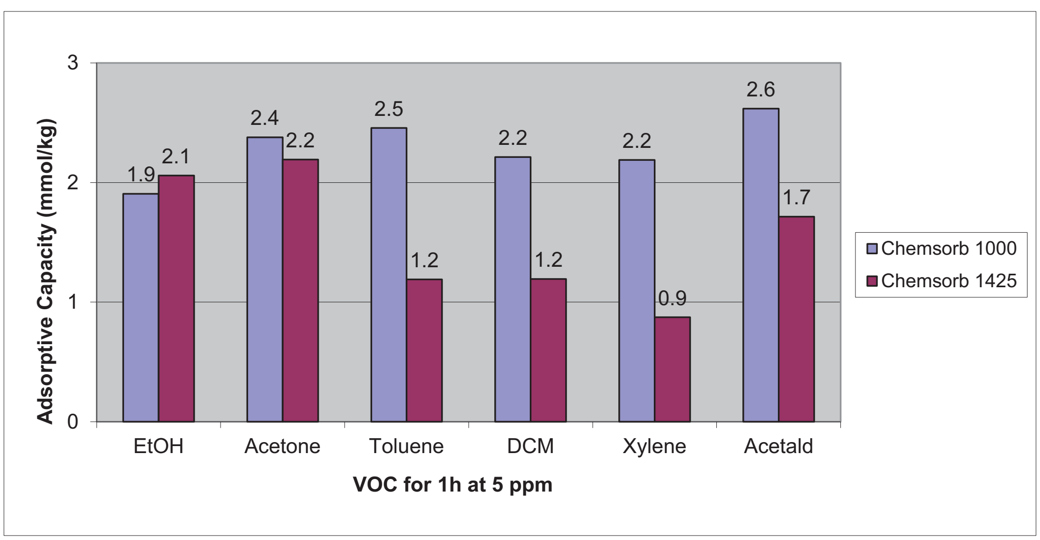

Figure 4. *Comparison of 1-h Adsorptive capacities of moist Chemsorb 1425 and Chemsorb 1000 for ethanol, acetone, toluene, dichloromethane, xylene, and acetaldehyde.*

E. Chemsorb 1425 – Adsorptive Capacity for NH_3

Chemsorb 1425 (9 grams) was loaded at 2 L/min containing 345 ppm NH_3 for 15 hours (Fig 5). The 1-h adsorptive capacity for NH_3 was 0.21 mol/kg. At breakthrough, which occurred after 5hrs, the adsorptive capacity for NH_3 was 1.05 mol/kg. The adsorptive capacity at 15 h for NH_3 was 2.4 mol/kg.

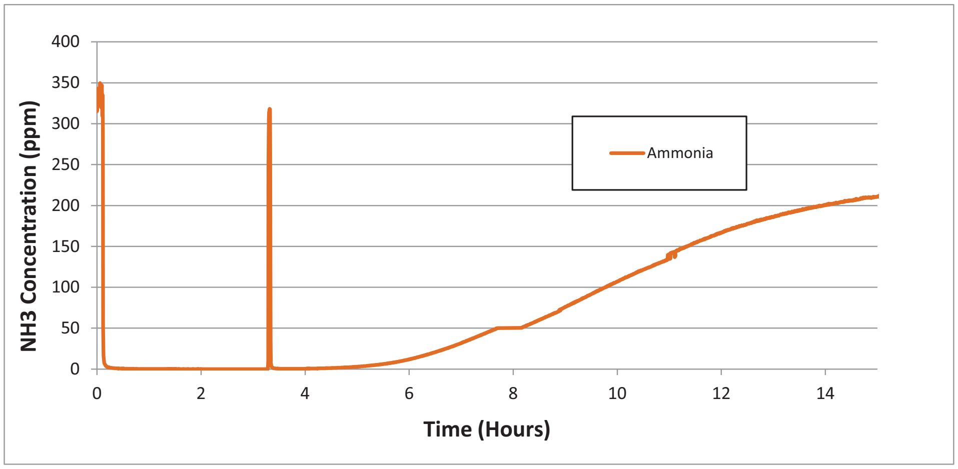

Figure 5. *Loading of Chemsorb 1425 with 2 SLPM of 345 ppm NH_3 at 40% RH. Breakthrough occurs at 5 hrs.The spike at 3.6 hrs shows when the bed was bypassed briefly to check the inlet NH_3 concentration. The adsorptive capacity of Chemsorb 1425 was not exhausted after 15 hrs of exposure to the inlet NH_3 gas stream.*

The adsorptive capacity of Chemsorb 1425 for NH_3 grew nonlinearly with time up to a maximum of 2.4 mol/kg (Fig 6). The maximum adsorptive capacity was obtained from data in Fig 5 at 15 h.

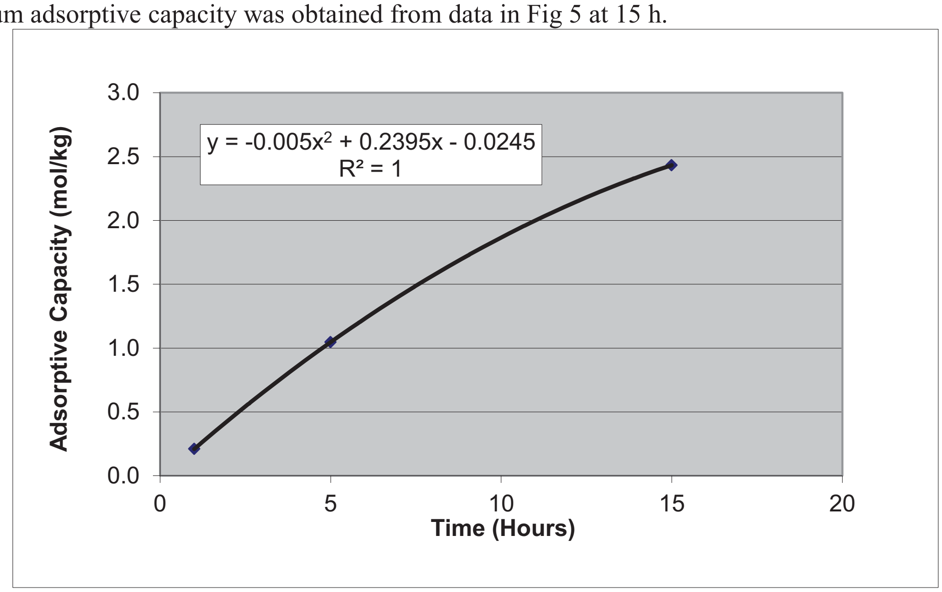

Figure 6. *The adsorptive capacity of Chemsorb 1425 increased nonlinearly with time as the bed was being loaded with 345 ppm of NH_3 at 40% RH. The maximum capacity after 15 h for NH_3 was 2.4 mol/kg.*

The 1-h adsorptive capacities of Chemsorb 1425 for NH_3 were measured at increasing inlet NH_3 concentrations (Fig 7). The adsorptive capacities rose from 15 mmol/kg at 50 ppm NH_3 to 153 mmol/kg at 300 ppm NH_3. For

comparison, Luna et al (2010)[3] reported an adsorptive capacity of NH_3 for B-S Type 3032 of 213 mmol/kg at 50 ppm NH_3 at 40% RH.

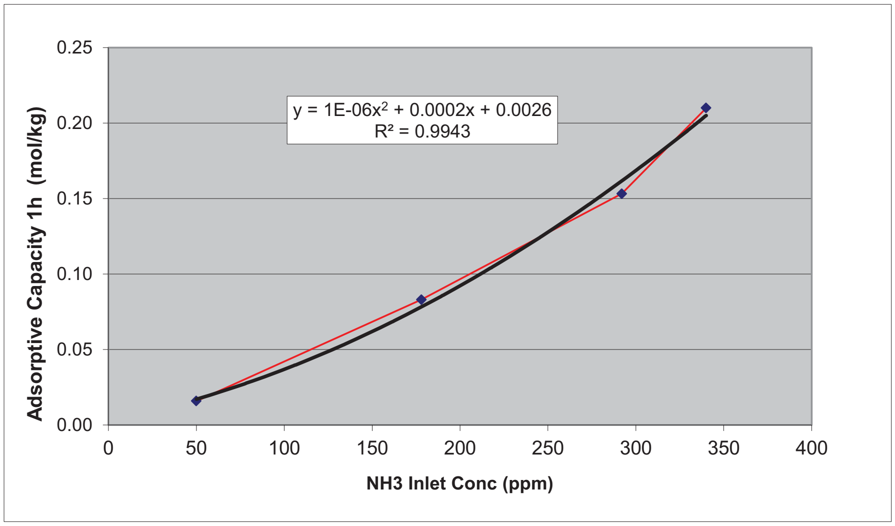

Figure 7. *The 1-h adsorptive capacity of Chemsorb 1425 increases as the inlet NH_3 concentration increases.*

IV. Conclusion

The adsorptive characteristics of Chemsorb 1000 and Chemsorb 1425 were studied. These data are useful for designing future air revitalization systems that use adsorbent beds to remove VOCs and NH_3 from spacecraft atmospheres. The 1-h adsorptive capacity is a rapid screening method that was used to compare the effect of moisture on adsorption and to detect differences between the sorbents when challenged with low concentrations of contaminants typically found in spacecraft atmospheres. However, it may not be representative of the true adsorption potential of the sorbents and an improved method needs to be developed. Further work should include examining the effect of particle size on adsorptive capacities, the effect of adsorption at lower NH_3 concentrations, as well as determining adsorptive properties at higher relative humidities.

References

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